ANATOMY OF SOLANUM LACINIATUM AIT

by

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Introduction

In the last decade, pharmacological research work and pharmaceutical industry all over the world became keenly interested in vegetable raw materials with solasodine contents, permitting to produce steroid hormones by means of certain synthetizing steps. In Hungary, investigations have been performed for years in the Research Institute for Medicinal Plants in order to find the plant species supplying the most suitable glyco-alkaloid (7). The best among more than twohundred tested species for the time being has proved to be *Solanum aviculare* F o s t., belonging to the *Dulcamara* section (3). Further investigations have shown that the species known by the name of *Solanum aviculare* F o s t., which is found in many European Botanical Gardens, is nothing else but *Solanum laciniatum* A i t.

Partly on the ground of original investigations and partly by comparing the pertinent literature, the authors referred to have thoroughly discussed the taxonomic differentiation of the two species and have published data on morphological and cytological conditions (chromosome number) of *Solanum laciniatum* and *aviculare*.

We were encouraged by the pharmaceutical importance of *Solanum laciniatum* to discuss, with due knowledge of the external morphological conditions of the species, – after due identification – more thoroughly the internal structure of that species.

The *Solanum* genus consists of species of extremely varied contexture with generally clear-cut morphological differences between each other. On account of their outstanding economic importance, *Solanum tuberosum* and *S. lycepersicum* were treated in details by several authors with a view to anatomy; other species of the *Solanum* genus, however are histologically not known at all. In his comprehensive work on dicotyledonous plants, M e t c a l f e (12) mentions only *Solanum tuberosum*, *S. lycopersicum* and *S. dulcamara*. Pharmacognostic literature does not contain either any detailed data

on *Solanum* species with solasodine contents. As far as *Solanum laciniatum* is concerned, elaborated issues include the shape and number of chromosomes, the dimension of pollen, the presence of stone-cell groups (sclereids), and their relative size compared with that of seeds (13) (8). In order to obtain a thorough knowledge of the species and to be able to carry out taxonomic identification, we thus have to study its basic histological structure.

Using a selected material (for which the author is indebted to the Research Institute for Medicinal Plants), we have sampled well developed stems in the state of inflorescence and have studied the histological conditions of Solanum laciniatum Ait. in various sections and clarified preparations. The results are specified for each organ separately.

Results

The Root

The root of the young seedling is divided into the rhizodermis, the primary cortex and the central cylinder (Fig. 1.). The rhizodermis consists of thin-walled tight fitting cells with plasma contents, most of them elongating into root hairs of ½ to 1 mm length. Placed underneath, the primary cortex consists of thin-walled, rounded-off parenchyma-cells with plasma contents; it is formed

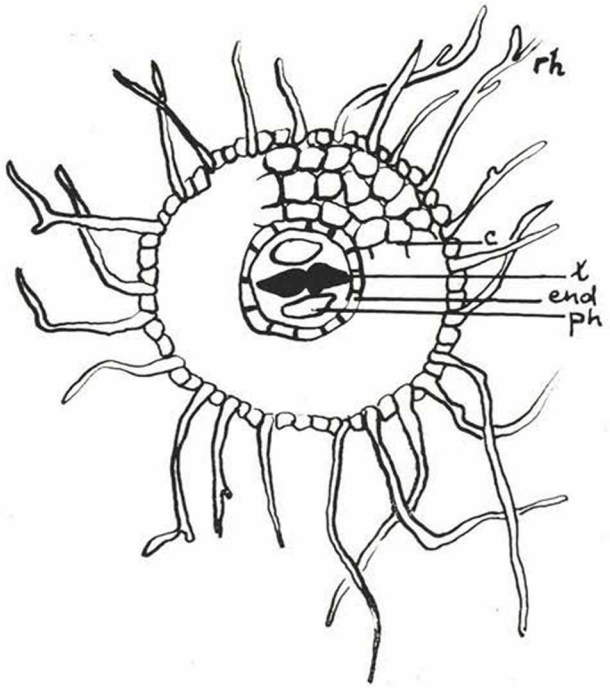

Fig. 1. Schematic transection of young root. rh = rhizodermis, c = primary cortex, end. = Casparian endodermis, x = xylem, ph = phloem

of 6–7 cell layers , accumulating stored starch and divided by intercellular spaces. The primary cortex is terminated by a Casparian line of one cell-row thickness. Next to this line, in the central cylinder, there is a parenchymatic pericambium composed of two cell rows and widening out towards the xylem bundles into 3–4 cell rows. The supply tissue system is diarche, i. e. it consists of two simple, opposite xylem bundles with two phloem bundles between them. Containing only a few tracheae and tracheids, the xylem bundles meet in the middle, without any pith between them. The phloem bundles are composed of sieve tubes, companion cells and phloem parenchyma.

As the root grows, the root hairs are pressed together and soon die off. Simultaneously, some of the external cell rows of the primary cortex get transformed into exodermis, because suberose substance penetrates gradually into their cell wall. A soon as the exodermis has been formed, the secondary increase of the vascular tissue system sets on. The process is introduced by the formation of the root cambium, taking the shape of a continuous wavy layer inside the phloem bundles and outside the xylem bundles. The cells of the root cambium are oblong in form, rich in plasma, tight fitting and readily stainable. This meristem layer produces inwards uniform xylem elements while phloem elements outwards. Due to its activity, the vascular system becomes continuous. In the centre of the root, however, the primary xylem bundles continue to be clearly recognizable.

Later on, the histological structure of the root is subject to further changes. In the primary cortex under the exodermis paracambium is formed which, acting in a dipleuric way, produces outwards the phellom and inwards fundamental tissue (parenchyma). In conbrast to many dicotyledonous plants, the primary cortex subsists at an advanced age without becoming detached from the stele of the root (9).

On several points, calcium oxalate crystal sand can be observed in the cells of the primary cortex and the ground tissue cells of the stele. The crystal holder cells are large-sized idioblasts stretched towards the longitudinal axis. In the primary cortex there are also sporadic lignified giant cells with thick cell walls (Fig. 2.).

Even in older roots, the cortex-line is often a Casparian endodermis. On account of the deposition suberic-laths, it later becomes subdivided and transformed into a tertiary endodermis. A dilatation ground tissue zone of 4–5 rows is formed underneath, composed of parenchyma cells which are tangentially markedly elongated due to the thickening of the root. Where two calcium oxalate crystal sand is present.

The phloem body is divided into cuneiform phloem groups by conically widening rays (dilatation increase). Fibres appear only in the primary phloem as a subsequent process.

The dispersed arrangement of the tracheae is characteristic of the xylem body. Single pores are the most frequent, but twin pores and groups of pores can also be observed. The thickening of their wall is pitted and sometimes spiral. As in the case of other *Solanum* species, the perforation is simple (12) (Fig. 3.). Tracheids are less frequent, the wall-thickening is also pitted. The basic stock of the xylem is composed of wood-fibres, with simple pitted wall-thickening. The wood-parenchyma is of paratracheal arrangement and surround

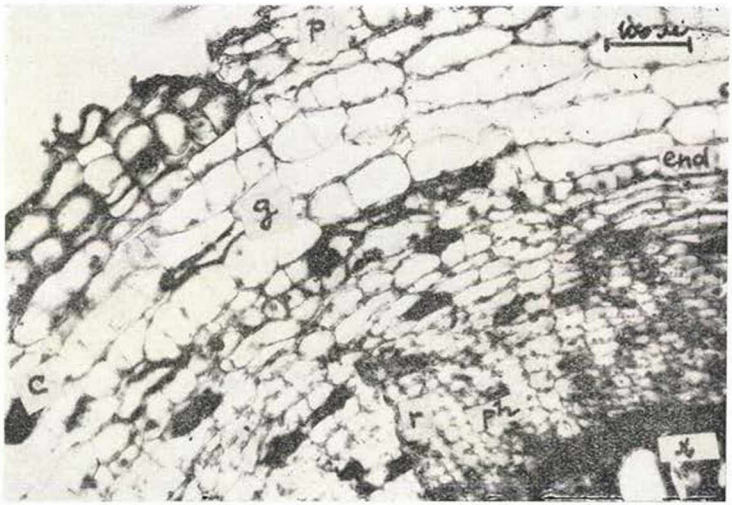

Fig. 2. Primary and secondary cortex of older root. p = periderm, g = giant cell, c = criystalsand holding cell, end = Casparian endodermis, ph = phloem body, r = dilated ray, x = xylem body

the tracheae biseriately, as in the case of other *Solanum* species (12). The rays are 1 – 2 cell-rows wide.

The formation of lateral roots presents the course generally characteristic of dicotyledonous plants.

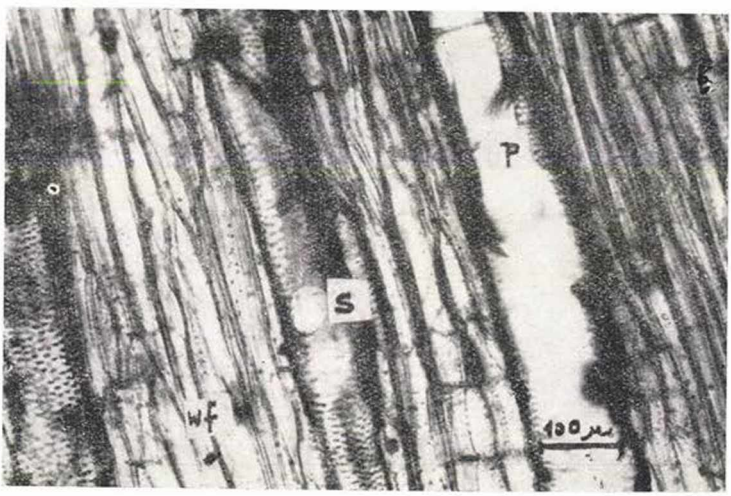

Fig. 3. Longitudinal section of the root' s xylemm body. s = simple perforation in the trachea, p = pitted thickening of cell-walls, wf = wood-fibre

The Stem

The stem is differentiated from the meristematic tissues of the growing point of the shoot; among its primary tissue systems, the dermal tissue system is the first to be named here. The epidermis of the seedling's hypocotyl is of a characteristic formation. Seen from above, its cells are of an elongated oblong-form, with plugged wall-thickening. Typical hair structures can be found sporadically, which are not observed anywhere else on the plant. These are glandular hairs composed of a three-cell stalk and a single-cell head.

Seen from above, the epidermis of the young stem is composed of hexagonal tight fitting parenchyma cells. Its thicker external cell-wall is covered with a shrivelled cuticle layer. Stomata are formed here and there. (For further details on their structure see chapter on the leaf.)

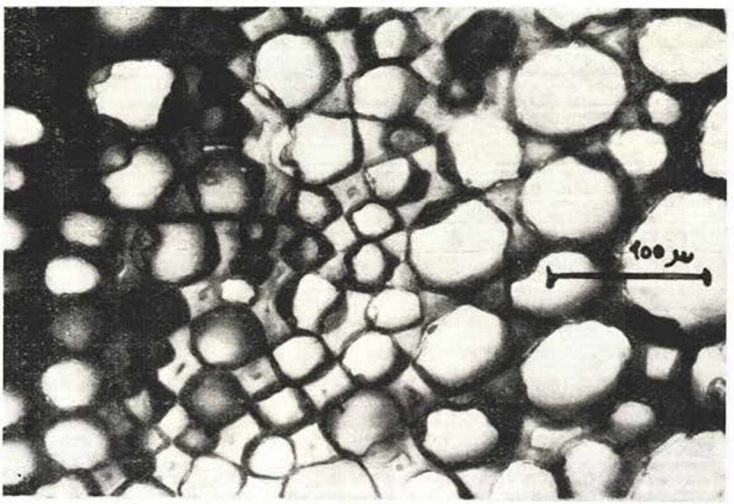

Fig. 4. Collenchyma tissue of the stem, with angular-thickening (detail)

Under the epidermis follows a chlorenchymatic hypodermis consisting of 2 to 3 cell-rows. This is succeeded by a broad, angular collenchyma tissue formed of 10–15 cell-rows, reaching as far as the cortex line (Fig. 4.). The primary cortex is closed towards the stele by a uniseriate starchy sheath.

The pericycle of the stele is a bi-or triseriate broad parenchyma tissue. The vascular system is placed beneath it; initially it is of a fascicular structure. Growing in the direction of the 4 to 6 ribs developing on the stem, the larger primary vascular bundles are open and of a collateral structure. Their xylem elements are of spiral and annular wall-thickening. The side of the xylem adjacent to the pith is framed with several (often six) interior phloem groups, anastomizing often in the Solanum family with the external phloem groups (1). Anastomosis can be also observed in *Solanum laciniatum* A i t. In the pith crown the subsequent formation and activity of cambium can bring about adventitious phloem bundles later too, which penetrate into the pith tissue (12).

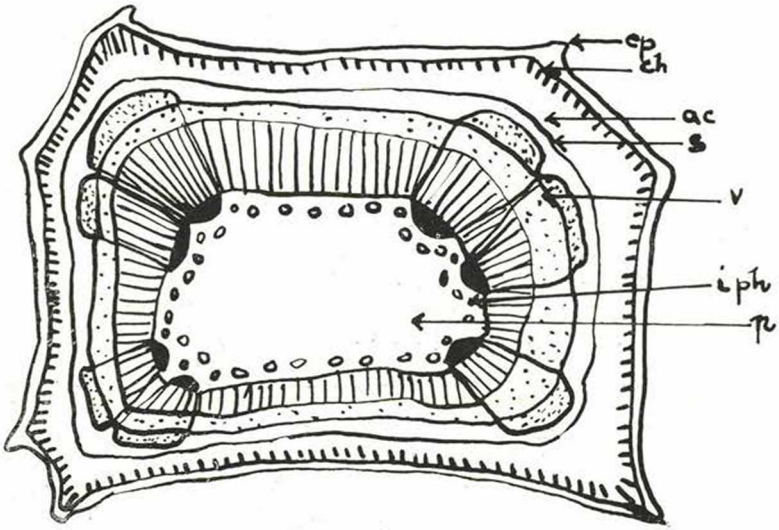

Fig. 5. Schematic generalview of the stem. ep = epidermis, ch = chlorenchyma, s = starch sheath, ac = angular-collenchyma, v = vascular bundle, iph = internal phloem, p = pith

In the course of stem development, an interfascicular cambium appears soon in the ray between the bundles, producing further collateral bundles. They will be always more closely set, until at last the conducting system becomes continuous (Fig. 5.). In the course of thickening, the internal phloem bundles are disunited, surrounding the pith tissue in uniformly arranged groups (Fig. 6.).

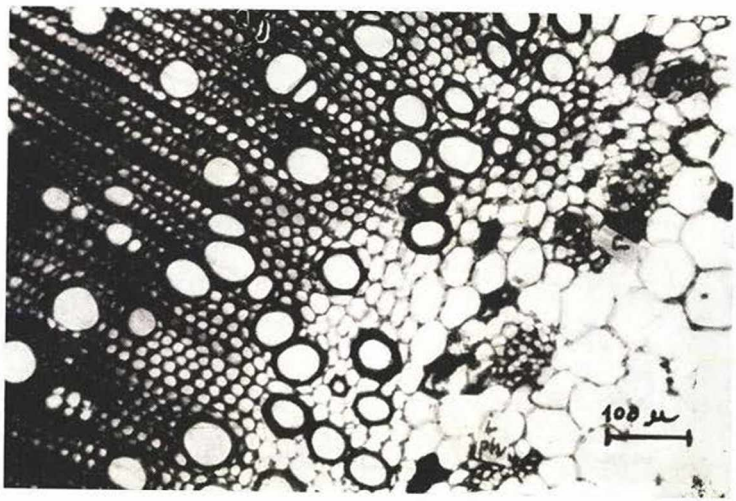

Fig. 6. Inner phloem groups in the stem. i. ph = internal phloem, c = crystal-holding cell

Idioblasts containing calcium oxalate crystal sand can be frequently found in the parenchyma of phloem and xylem, as well as in the uniseriate rays (Fig. 7.). In old stems, fibre groups can be observed on the border of the primary phloem.

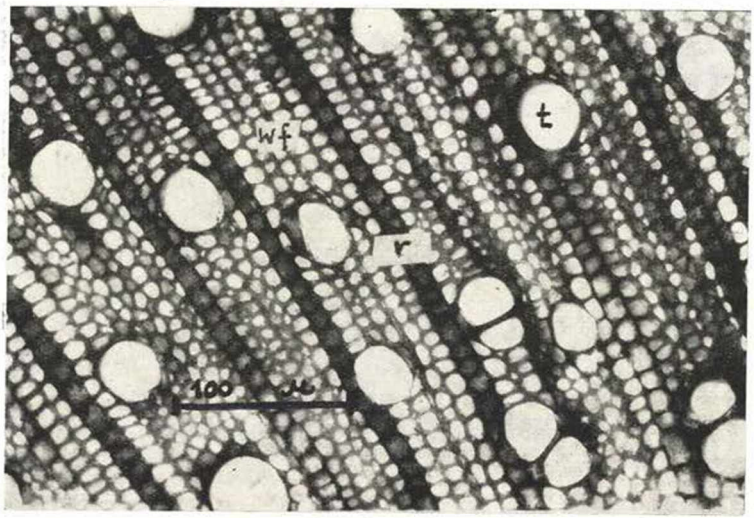

Fig. 7. Detail of the xylem body of the stem. t = trachea, r = ray, wf = wood fibre

The Leaf

The cotyledon of the germinating plant is of isolateral structure. Its upper and lower epidermis is composed of polygonal cells without tricho mes. The stoma-structure is of the Cruciferae type, with 1 – 3 subsidiary cells.

The base of the fully developed leaf is insignificant, its petiole is of cylindric formation. The epidermis of the petiole is uniseriate, composed of thin-walled polygonal cells. The chlorenchymatic hypodermis consists als of a single row of cells, with the angular-collenchyma tissue placed underneath. The cortex border is a starchy sheath. The vascular tissue remains fascicular all along. Internal phloems are also developing here. It is characteristic of the xylem that its trachease are radially arranged. The vascular bundles are surrounded by cells holding calcium oxalate crystal sand. The fundamental tissue is a loose thin-walled parenchyma.

The leaf blade is of bifacial structure. Seen from above, its upper epidermis consists of polygonal tight fitting cells (Fig. 8.). The cells of the lower epidermis have sinuous walls and are equally tight fitting. On both the upper and the lower epidermis, stomata can be found in dispersed arrangement, numbering 100 – 110 per sq. mm on the upper and 180 – 200/sq. mm on the lower one. The stomata are surrounded by three subsidiary-cells, their structure is of the *Cruciferae* type, like in other members of the *Solanaceae* family (12). The glandular hairs on the epidermis consist of a stalk of 1 – 2 cells and of a head of 6 to 8 cells. Their frequency amounts to 1 to 2/sq mm on the upper and to 3 to 4/sq. mm on the lower epidermis.

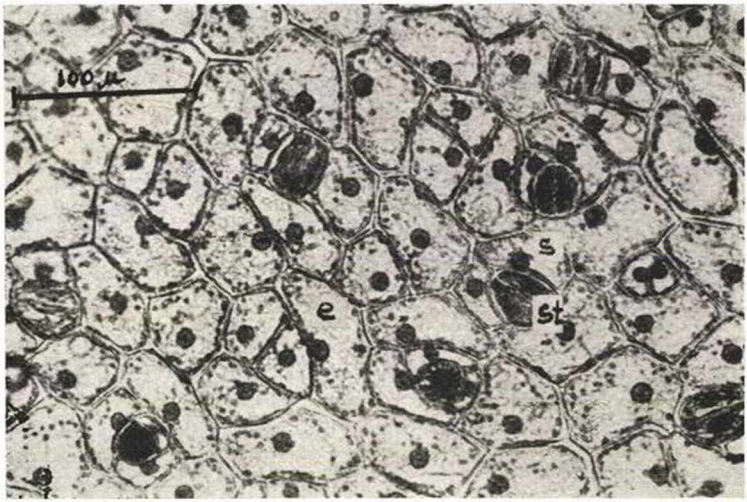

Fig. 8. Upper-epidermis of the leaf. st = stoma, s = subsidiary cell, e = epidermis cell

Two or three of the elongated cells of the uniseriate palisade-parenchyma end at 1 collecting cell each. The spongy parenchyma is of a loose structure and consists of 4 to 6 cells rows (Fig. 9.).

The structure of the vascular-bundles of the mid-rib is similar to that of the bundles of the petiole. Here too, the interior phloem groups can be readily observed. In the fundamental tissue surrounding the bundles of the leaf, several crystal-holding cells can be observed, containing calcium oxalate crystal sand. The fundamental tissue of the mid-rib is isodiametric parenchyma.

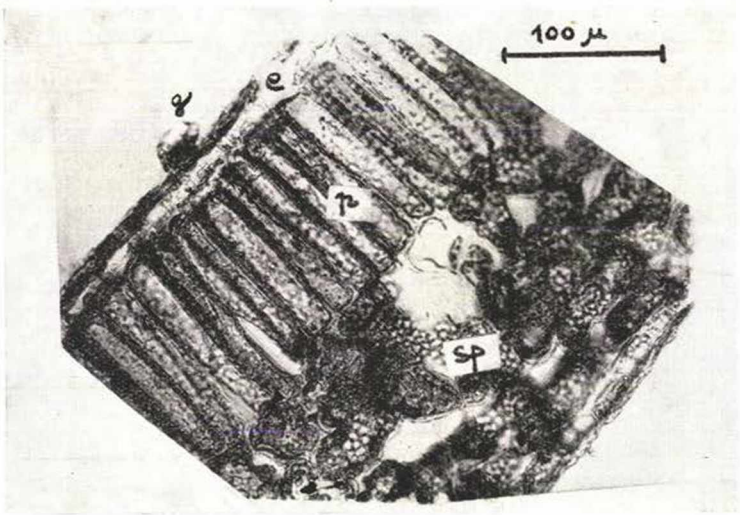

Fig. 9. Transection of leaf. e = epidermis, g = glandular hair, p = palisade parenchyma, sp = spongy parenchyma

No palisade-parenchyma is formed here. On the lower side, the mid-rib is strongly protruding; a collenchymatic hypodermis is formed here under the epidermis.

Seen from above, irregular polygonal nervure isles can be observed on clarified preparations. The number of nervure isles per 2 sq. mm amounts to 8. The tracheids of the bordering veins are of spiral wall-thickening. The protruding veins are rarely bifurcated, they are mostly simple, with a butt-end (Fig. 10.).

The Flower

Seen from above, both epidermises of the sepals are composed of polygonal cells. Stomata similar in structure to the foliage leaves can also be observed. Typical Solanaceae glandular hairs, with stalks of 1 to 2 cells and heads of 6 to 8 cells, are droeloping densely on the outer epidermis (Fig. 11.). In cross-section, the sepals are of isolateral structure. Their fundamental tissue consists of loose parenchyma. The vascular bundles are collateral and closed.

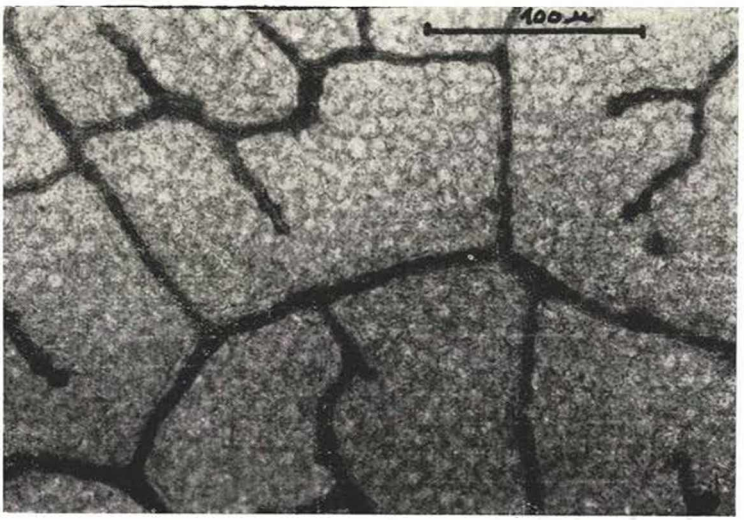

Fig. 10. Venation-isles in the clarified leaf.

The inner epidermis of the corolla is of papillar surface. Both epidermises are covered with a shrivelled cuticle. The epidermis cells of the corolla tube are oblong and elongated. Covering hairs of 2 to 3 cells, with strongly stained plasma contents, can be found here, with cuticular modi of characteristic form on them (Fig. 12.). The fundamental tissue of the corolla is a loose, spongy parenchyma. Particularly in the corolla tube, its nervure isles are elongated and closed (Fig. 13.).

On the average, the pollen grains are 40 micron in diameter, of rhomboidal shape, with three tapering exit holes (Fig. 14.). Their surface is of irregular reticular wall-thickening (5).

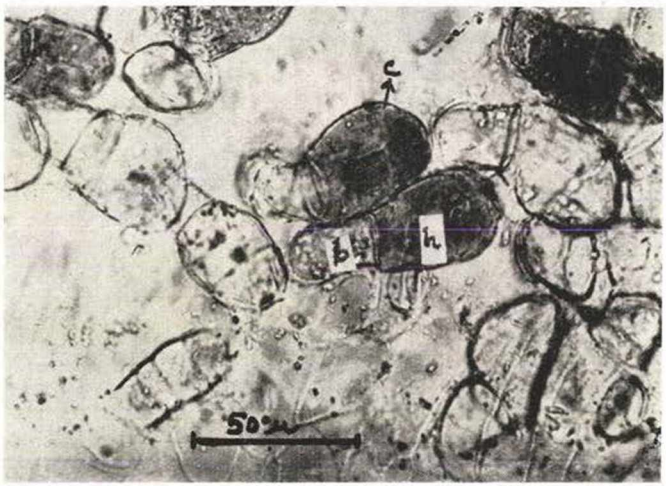

Fig. 11. Characteristic *Solanaceae* glandular hairs on the clarified calyx.
c = cuticle, h = head cell, b = body-cell

The most characteristic feature of the pistil is the histological structure of the ovary. In cross-section it is covered with small quadrangular thickwalled epidermis cells, protected by a thicker cuticle. Sporadically arranged stomata can also be observed. There are no hair stuctures. The hypodermis is a collenchyma of a few cell rows. The fundamental tissue is otherevies a loose parenchyma. Chloroplasts can be found in its cells, especially near the synepidermis. The vascular bundles are collateral, with characteristic internal phloems. The innermost layer of the ovary wall consists of a thin-walled parenchyma.

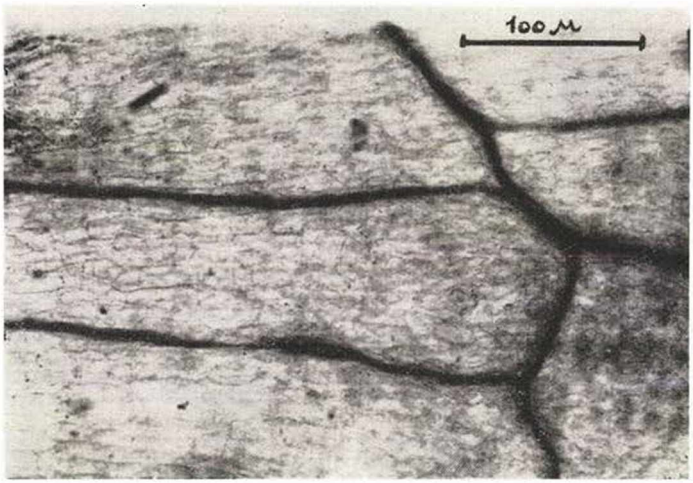

Fig. 12. Venation isles in the corolla, on a clarified preparation

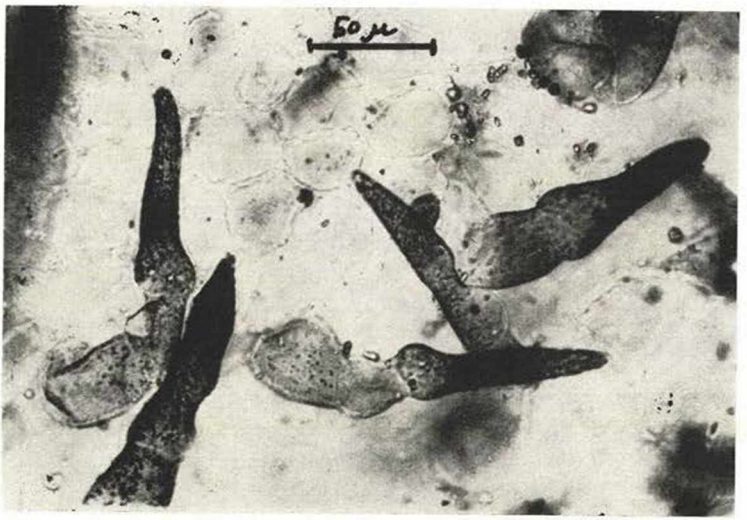

Fig. 13. Covering hairs in the corolla, stained with toluidine blue

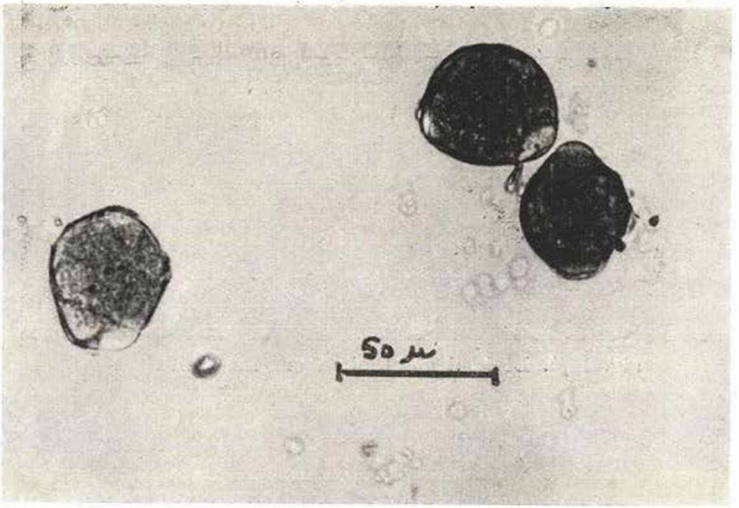

Fig. 14. Pollen grains from a clarified preparation

The Fruit

Fertilization induces the formation of the embryo and the development of the seed, while characteristic changes of the pistil tabe place. The ovary wall increases vigorously, it becomes thick and fleshy. As the fruit ripens, its green colour gradually changes into orange. The chloroplasts in the cells of its fundamental tissue are transformed into chromoplasts.

The wall of the ripe fruit is divided into exocarp, mesocarp and endocarp. The exocarp is uniseriate, composed of thick-walled cells which are covered by

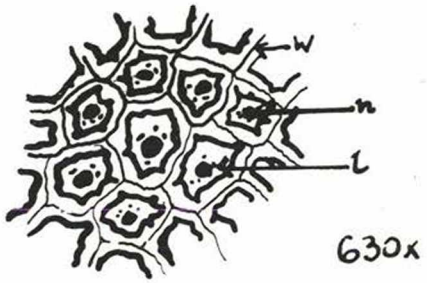

Fig. 15/*a*. Epidermis of fruit wall seen from above. w = cell wall, n = nucleus, l = leucoplast

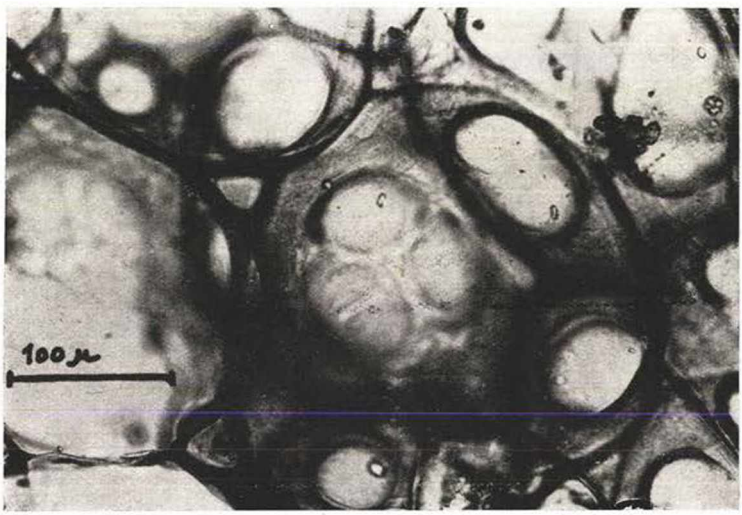

Fig. 15/*b*. Divided giant pits from the fruit-flesh

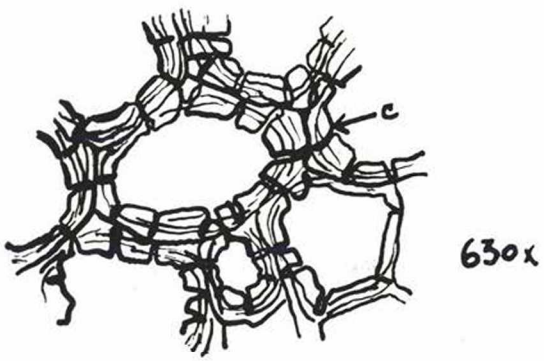

Fig. 15/c. Part of the stone cell group. c = channel-type cell wall thickening

a cuticle (Fig. 15/*a*.). A collenchymatic hypodermis of several cell rosw follows underneath. The bulk of the mesocarpium is formed of thin-walled, gradually increasing, sappy parenchyma cells. Huge, compound pits can be observed in the cell-walls (Fig. 15/*b*); L i n s b a u e r (11) refers to such pits in tomato This structure lends to the mesocarp a transfusion nature. Starch, aleurone and fatty oil drops are accumulated in the parenchyma, while small gradually fiberized vascular bundles are embedded in the fundamental tissue. The endocarp consists of uniseriate, thin-walled, slightly compressed cells.

It is characteristic of *Solanum laciniatum*, that there are stone cell groups (sclereid-groups) formed in its pericarp, increasing gradually as ripening gets on. Often they become bigger than the seed and break away from the flesh of the pericarp-wall as independent structures. Examined in cross-section, the stone cell groups are composed of irregular polygonal tight fitting cells with very thick walls; the thickening of the latter is of the channel type; the cells do not contain any plasma (Fig. 15/c.).

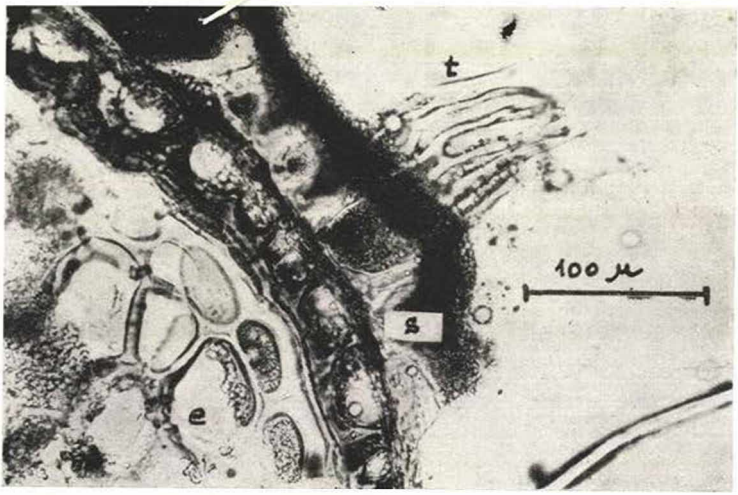

Fig. 16. Cross-section of seed-coat. t = trichome, s = stone-cell, e = endosperm

The developing seeds are closely embedded into the pericarp (Fig. 16.). There is a characteristic layer of the seed-coat, consisting of stone cells, with a structure similar to that of *Datura stramonium* (14). Outside this layer develops the proper epidermis of the seed-coat: a thin-walled uniseriate layer consisting of palisade-like elongated cells, with cell-wall lattices built-in while ripening. Initially this layer is entwined with the endocarp of the developing pericarp wall, but during the ripening of the seed the common wall is being absorbed and the cell-wall lattices are standing apart like the covering hairs (11). A similar organization of the seed-coat of tomato is referred to by E a m e s (4). In the ultimate analysis, the external layer of the fully ripe seed is supplied by the stone cells (sclereids) which, seen from above, have sinuous walls and uneven surface. Musous cell-wall flexures penetrate into

their vacuoles. Wall and vacuole are of brown colour, a phenomenon referred to by other outhors too in connection with different *Solanaceae* (11, 2). The stone cell layer is followed by a compressed parenchyma layer and subseguently by a fibre layer with lignified walls and pitted wall-thickening, which is the actual closing layer of the seed-coat. The perisperm is present in scraps only. The endosperm consists of well developed polygonal parenchyma cells, containing heterogenous aleurone grains and fatty oil drops in abundance.

The embryo is composed of meristematic tissues.

Summary

The anatomic conditions of the vegetative and reproductive organs of Solanum laciniatum Ait., were examined and detailed data particularly on the formation of the root cortex, the structur of the stem, the nervure isle and stomatic conditions of the clarified leaf, as well as on the formation of the pericarp and of the seed-coat were supplied.

РЕЗЮМЕ

Автором были обсуждены анатомические условия вегетативных и репродуктивных органов Solanum laciniatum Ait. Публикуются подробные данные особенно о развитии коры корня, о структуры стебля, а такжеоформировании наплодника и сменной оболочки.

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